

Two- and Three-Dimensional Analytical Microscopy with Ions, Electrons and Photons

Scientific Achievement

High efficiency and versatility make the new generation of analytical instruments developed at ANL-MSD capable of performing, with unprecedented sensitivity, two- and three-dimensional characterization of nanoscale samples to reveal elemental, isotopic and molecular compositions. These Secondary Neutral Mass Spectrometers with Laser Post-Ionization (LPI SNMS), incorporate a combination of the most efficient and accurate analytical tools and regimes identified over several decades of development of Secondary Ion Mass Spectrometry (SIMS) and benefit from several orders of magnitude higher (compared to SIMS) ion intensities due to the implementation of laser post-ionization. The new instruments perform time-of-flight mass analysis of photo-ions formed from neutral species emitted by solid surfaces during interactions with beams of ions, photons and electrons, and they can also detect secondary electrons emitted in the same processes. Analytical beams can be focused to submicron spots: 10-30 keV ions and electrons into 50-100 nm (down to 5-7 nm with new generation ion and electron guns) and laser photons to 0.5 μm . Raster scanning of these beams over the analyzed surfaces produces mass selected ion images and energy filtered secondary electron images with resolutions defined by the corresponding beam spot size. At the same time, the analyzed spot can be viewed through an in-vacuum optical microscope with 0.5 μm resolution. The third dimension of analysis (depth) is implemented by low energy (<1 keV) normally incident ion bombardment, which can gently remove the top atomic monolayer without damaging underlying ones. The analytical beams combined with low energy ion sputtering and high precision sample positioning (~ 10 nm) thus can probe sample composition in three-dimensions with depth resolution of one atomic monolayer and lateral resolution of up to 10 nm.

Significance

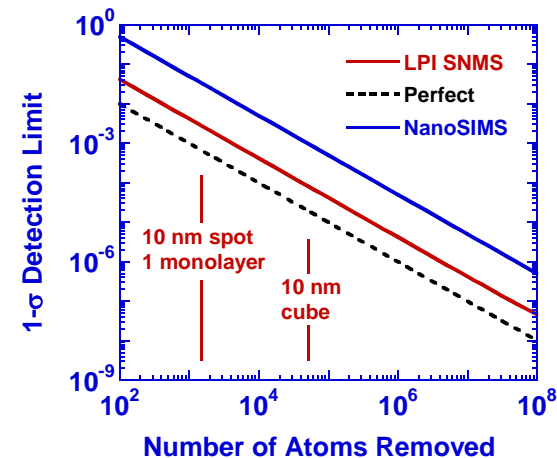
This new LPI SNMS tool for Nanometrology can enable a wide range of new nanofabrication technologies similar to how SIMS enabled advances in the field of semiconductors. Presently there is no other means to measure elemental, molecular and isotopic abundances in nanoscale objects. Beyond that, using this new instrumentation in basic studies of directed energy interactions with surfaces on the nanoscale will result in fundamental understanding of these processes, which will encourage new technological developments. Unprecedented sensitivity of this new instrumentation has generated strong interest in the scientific community as indicated by an invitation to present its description at the 18th International Conference on the Application of Accelerators in Research and Industry. First results of this work have been also published in: *Nucl. Instr. Meth. B* **219-220**, 473 (2004) and *Appl. Surf. Sci.* **231-232**, 962 (2004).

Performers

Igor Veryovkin, Emil Tripa, Wallis Calaway and Michael Pellin (ANL-MSD)

Two- and Three-Dimensional Analytical Microscopy with Ions, Electrons and Photons

- A new Laser Post-Ionization Secondary Neutral Mass Spectrometer (LPI SNMS) permits three-dimensional elemental, isotopic and molecular trace analysis.
 - High sensitivity allows nanometer trace analysis.
 - Focused ion and electron beams deliver lateral resolutions of 50–100 nm
 - Low-energy, normal-incident ion milling yields a depth resolution of one atomic layer.
- A new generation liquid metal ion source (~5 nm beam spot) will further improve lateral resolution.



Efficient detection is paramount when samples have limited numbers of atoms.

